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ORIGINAL ARTICLE

Speech perception in noise in unilateral hearing loss☆

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KEYWORDS
Speech perception;
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Abstract

Introduction: Unilateral hearing loss is characterized by a decrease of hearing in one ear only. In the presence of ambient noise, individuals with unilateral hearing loss are faced with greater difficulties understanding speech than normal listeners.

Objective: To evaluate the speech perception of individuals with unilateral hearing loss in speech perception with and without competitive noise, before and after the hearing aid fitting process.

Methods: The study included 30 adults of both genders diagnosed with moderate or severe sensorineural unilateral hearing loss using the Hearing In Noise Test - Hearing In Noise Test-Brazil, in the following scenarios: silence, frontal noise, noise to the right, and noise to the left, before and after the hearing aid fitting process.

Results: The study participants had a mean age of 41.9 years and most of them presented right unilateral hearing loss. In all cases evaluated with Hearing In Noise Test, a better performance in speech perception was observed with the use of hearing aids.

Conclusion: Using the Hearing In Noise Test-Brazil test evaluation, individuals with unilateral hearing loss demonstrated better performance in speech perception when using hearing aids, both in silence and in situations with a competing noise, with use of hearing aids.

PALAVRAS-CHAVE
Percepção da fala;
Perda auditiva unilateral;
Ruído

Percepção da fala no ruído em perda auditiva unilateral

Resumo

Introdução: A perda auditiva unilateral (PAUn) é caracterizada pela diminuição da audição em apenas uma orelha. Em presença de ruído ambiental, indivíduos com PAUn encontram maiores dificuldades que os ouvintes normais para compreender a fala.

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Objetivo: Avaliar o desempenho de indivíduos com perda auditiva unilateral, na percepção da fala sem e com ruído competidor, antes a após adaptação do AASI.
Método: Estudo com 30 adultos, e de ambos os sexos, com diagnóstico de perda auditiva unilateral sensorioneural, de graus moderado e severo, utilizando o *Hearing In Noise Test* – HINT – Brasil, nas seguintes situações: silêncio, ruído à frente, ruído a direita e ruído a esquerda. Antes e após adaptação do AASI.
Resultados: Os participantes da pesquisa apresentavam média de idade de 41,9 anos e PAUn predominante à direita. Em todas as situações propostas pelo HINT foi constatado melhor desempenho na percepção da fala com o uso do AASI.
Conclusão: No teste HINT – Brasil, indivíduos com PAUn demonstraram melhor desempenho na percepção da fala, em tanto no silêncio quanto nas situações com ruído competidor, com uso do AASI.

Introduction

Individuals with unilateral hearing loss (UHL) have limitations of communicative activities, especially in noisy environments,[1] as well as possible deficits in auditory processing that potentially affect the development of language and communication.[2]

Binaural hearing provides sound localization, binaural summation, a shadow effect of the head and release from masking. The interaction of these factors favors speech recognition in noise, due to the ability to perform figure-background.[3]

As a whole, UHL can cause difficulties in communication.[4] This problem can be minimized with the use of individual sound amplification devices (hearing aids), which allows rescuing the perception of speech sounds, as well as of environmental sounds, helping to improve conversational ability.[5]

Sound amplification is an option for individuals with hearing loss, but in isolation such devices may have limited effectiveness in assisting speech understanding in noisy environments, or in the presence of reverberation. People with UHL experience difficulties in the discrimination of unusual signals, an automatic ability in subjects with normal hearing.[6] This component requires special attention on the part of the speech therapist when selecting and verifying hearing aid devices.

In Brazil, tests of speech perception that use a competing noise are not yet part of the conventional audiological evaluation protocol, and based on protocols the comparison of performances in quiet and in noisy environments is not often made.[7]

In order to best represent everyday listening situations, over time the use of sentences in speech perception tests, with and without the presence of a competing noise was introduced.[7,8]

When reaching 50% of intelligibility, speech perception tests that measure the speech signal recognition threshold in a quiet environment detect only small differences between individuals with normal hearing and those with hearing loss, in contrast to when these people are exposed to noise and intelligibility declines.[9]

The Hearing In Noise Test (HINT) was developed in 1994,[10] to measure the difficulty to recognize speech, and to compare the findings with the results of individuals with normal hearing, both in quiet and in noisy environments. The methodology proposed by HINT enables the use of thresholds in signal/noise (*S*/*R*) ratio to evaluate speech recognition in noise, instead of using the percentage of correct answers.[7]

There are many factors that negatively impact the ability to understand speech during evaluation, including the characteristics of the subject evaluated, together with his/her experiences on language and hearing, the type and level of presentation of the material, and the answers produced.[11] Thus, the importance of studying speech perception in tests that simulate the perception of the speech signal in the presence of a competitive noise is evident.

Therefore, this study aimed to assess speech perception of individuals with unilateral hearing loss in conditions with and without a competitive noise, with and without the use of hearing aids.

Methods

The study was approved by the Ethics in Research Committee of the institution where it was conducted (Protocol No. 095/2010).

To be included in the study, participants had to meet the following inclusion criteria: adults aged 18–50 years, diagnosed with moderate to severe sensorineural UHL, and with contralateral hearing within normal limits who did not use hearing aids.

The hearing loss classification was based on the mean of audiometric thresholds at frequencies of 500; 1000; 2000; and 4000 Hz, characterized as mild (mean 26–40 dB HL), moderate (average 41–60 dB HL), severe (average 61–80 dB HL), and profound (average above 81 dB HL) hearing loss according to the World Health Organization (WHO).[12]

Table 1 Distribution of the sample by gender, ear with sensory deprivation, and degree of hearing loss.

	Degree of hearing loss					
	F % (*n*)	M % (*n*)	% (*n*)	Moderate % (*n*)	Severe % (*n*)	% (*n*)
LE	36.84% (7)	63.64% (7)	46.7% (14)	42.86% (6)	57.14% (8)	46.7% (14)
RE	63.16% (12)	36.36% (4)	53.3% (16)	50% (8)	50% (8)	53.3% (16)
Total	63.3% (19)	36.7% (11)	100% (30)	46.7% (14)	53.3% (16)	100% (30)

RE, right ear; LE, left ear; F, female; M, male.

The study included 30 subjects with a mean age of 41.9 years; 46.7% of them had moderate hearing loss and 53.3% had severe hearing loss. Table 1 lists the characterization of the study participants regarding gender, ear affected by sensory deprivation, and degree of hearing loss.

For selecting the type and model of the hearing aid device, the auditory characteristics and communicative needs of the participants were analyzed. According to this analysis, the following hearing aids were selected: Phonak Una® M AZ and Una® SP AZ, suited for moderate and severe hearing loss, respectively.

After programming of hearing aid devices, a verification procedure was carried out with measurements conducted with a probe microphone. REAR values were compared to targets of the NAL-NL1 rule for weak, medium and strong sounds. Answers were considered as matched when the difference between the target for REAR and the value obtained in an actual ear did not exceed 10 dB.[13] For all subjects, the answers were matched to the targets.

The study participants underwent an assessment of speech perception without hearing aids on the day of device adaptation. The test was repeated with the hearing aid three months after effective use of the device, which was defined as use $\geq$8 h/day for a period of three months, confirmed by data logging and considering the subject's adaptation.[14] The entire group of patients was required to maintain daily records of hearing aid usage, and on their return that data was utilized to verify the number of hours of use each day.

HINT

The test consists of lists of sentences, a competing noise, and a microprocessor that controls the test application. The stimulus used in this speech perception in noise test is the speech signal. To present the stimulus, the authors determined the speech recognition threshold needed for the subject to correctly identify 50% of speech stimuli in the established signal/noise ratio.

This value is determined by the HINT protocol, and has two phases. The first phase consists of the first four sentences; the intensity varies in increments of 4 dB. The second phase starts from the fifth sentence, and the intensity varies in increments of 2 dB, which gives greater accuracy in the determination of the threshold.[15]

The speech stimulus was presented frontally and in the absence of a competing noise. Then, the stimulus was presented with the speech signal and a frontal noise, followed by noise to the right and by noise to the left, while the speech signal was frontally positioned. The same procedure was carried out with and without the use of hearing aids. The noise intensity remained fixed at 65 dB HL and the stimulus intensity was adjusted to a greater or lesser value, depending on the answers obtained.

The HINT equipment has a standardized nomenclature for the four test conditions. When a correct answer is obtained, the *S*/*N* ratio decreases by an equivalent amount. When the answer is incorrect, the signal/noise (*S*/*N*) is increased by the same equivalent value.

The signal is presented through lists of sentences, and the noise used is that of the sentences used. A negative *S*/*R* ratio indicates greater difficulty during the test. Thus, the lower the *S*/*N* ratio is, the better the subject's performance in situations with a competitive noise.[15]

The test was conducted in an open field situation, and the speech reception threshold was obtained by applying 20 recorded sentences that simulate everyday situations. The four situations carried out are described below.

Speech without noise (S): the sign is emitted in front of the subject in a noise-free test condition (0° azimuth).

Speech with frontal noise (FN): the signal and the noise are placed directly in front of the subject in a noise condition at 0° azimuth.

Speech with noise to the right (NR): the signal is placed in front of the subject and the noise is emitted from 90° on the right of the signal (condition: noise to the right − noise at 90° azimuth).

Speech with noise to the left (NL): the signal is placed in front of the subject and the noise is emitted from 90° on the left of the signal (condition: noise to the left − noise at 90° azimuth).

Regardless of the way of application of HINT, the software itself calculates (in open field or with headphones) the compound noise (CN), which consists of a weighted average of the four conditions, as follows: $CN = (2 * FN + NR + NL)/4$.

The HINT results were expressed by the values of sentence recognition threshold (SRT) and were compared with the means obtained from subjects with normal peripheral hearing.

In the statistical analysis, the Fisher's exact test and Student's *t*-test were used, and a difference was considered to be statistically significant when $p \leq 0.05$.

Results

The sample of this study consisted of 30 subjects, with no difference between genders. All subjects had moderate (46.7%) or severe (53.3%) sensorineural UHL and with similar

Table 2 Comparison between ears with unilateral hearing loss in each situation proposed by the Hearing In Noise Test (HINT), without and with hearing aids.

Situation proposed by HINT	LE			RE			Difference between RE and LE
	n total	Mean	SD	*n* total	Mean	SD	*p*-Value
S1	14	40.18	4.82	16	41.01	4.97	0.64
S2	14	39.36	4.45	16	39.14	4.36	0.89
S_1_2	14	−0.82	3.51	16	−1.86	4.25	0.47
FN1	14	−1.50	1.39	16	−0.70	1.39	0.13
FN2	14	−1.62	1.33	16	−0.99	1.84	0.29
FN_1_2	14	−0.12	1.29	16	−0.28	1.09	0.71
RN1	14	−2.38	2.31	16	−3.24	2.42	0.33
RN2	14	−2.87	2.41	16	−3.87	1.96	0.21
RN_1_2	14	−0.48	2.11	16	−0.63	1.52	0.82
LN1	14	−3.54	2.01	16	0.36	1.70	0.00[a]
LN2	14	−3.63	1.79	16	−1.35	2.08	0.00[a]
LN_1_2	14	−0.09	1.57	16	−1.71	2.18	0.02[a]

S, silence; FN, frontal noise; NR, noise to the right; LN, noise to the left; 1, situation without hearing aids; 2, situation with hearing aids; *n*, number; SD, standard deviation; RE, right ear; LE, left ear.
[a] Statistically significant difference.

involvement of the ears – 46.7% on the left and 53.3% on the right ear (Table 1).

Table 2 shows the comparison between right and left ears affected by UHL in the four situations proposed by HINT (S, FN, NR, and NL), without and with hearing aids. Individuals with right UHL showed slightly better results, but the significant results were observed for the left ear responses in situations with noise on the left ($p \leq 0.02$).

Table 3 shows the comparison between the degree of UHL – moderate or severe – in four situations proposed by HINT (S, FN, NR and NL), without and with the use of hearing aids. It was observed that subjects with moderate loss presented best answers in all proposed situations.

Table 4 shows a comparison between the performances of male and female subjects with UHL in the four situations proposed by HINT (S, FN, NR, and NL), without and with the use of hearing aids, with significant results for females in S ($p \leq 0.02$), and NR ($p \leq 0.03$).

Table 5 shows the performance of the group of 30 subjects with UHL in those four situations proposed by HINT (S, FN, NR, and NL), with better results on NL, regardless of the affected ear.

Discussion

The presence of UHL raises several questions concerning the consequences of such loss, its etiology, and predominant

Table 3 Comparison of the degree of unilateral hearing loss in each situation proposed by the Hearing In Noise Test (HINT), without and with the use of hearing aids.

Situation proposed by HINT	MHL			SHL			Difference between MHL and SHL
	n total	Mean	SD	*n* total	Mean	SD	*p*-Value
S1	14	40.36	4.55	16	40.85	5.20	0.78
S2	14	37.96	2.50	16	40.36	5.29	0.13
S_1_2	14	−2.4	3.76	16	−0.48	3.90	0.18
FN1	14	−0.97	1.54	16	−1.16	1.36	0.73
FN2	14	−1.76	1.55	16	−0.87	1.63	0.13
FN_1_2	14	−0.78	1.15	16	0.28	0.97	0.00[a]
NR1	14	−3.77	1.77	16	−2.02	2.57	0.04[a]
NR2	14	−4.09	2.49	16	−2.80	1.78	0.11
NR_1_2	14	−0.31	1.62	16	−0.78	1.94	0.48
NL1	14	−1.72	2.90	16	−1.22	2.56	0.62
NL2	14	−2.55	2.13	16	−2.30	2.40	0.76
NL_1_2	14	−0.82	2.71	16	−1.07	1.34	0.75

S, silence; FN, frontal noise; NR, noise to the right; LN, noise to the left; 1, situation without hearing aids; 2, situation with hearing aids; *n*, number; SD, standard deviation; MHL, moderate hearing loss; SHL, severe hearing loss.
[a] Statistically significant difference.

Table 4 Distribution of subjects by gender in relation to situations tested by the Hearing In Noise Test (HINT), without and with the use of hearing aids.

Situation proposed by HINT	M			F			Difference between M and F
	n total	Mean	SD	*n* total	Mean	SD	*p*-Value
S1	11	37.49	3.16	19	42.44	4.76	0.00[a]
S2	11	38.19	5.40	19	39.85	3.59	0.31
S_1_2	11	0.70	3.97	19	−2.58	3.39	0.02[a]
RF1	11	−1.57	1.16	19	−0.78	1.51	0.15
RF2	11	−1.52	1.09	19	−1.15	1.88	0.55
FN_1_2	11	0.04	1.17	19	−0.36	1.18	0.36
NR1	11	−3.50	2.47	19	−2.46	2.29	0.25
NR2	11	−3.15	2.53	19	−3.55	2.04	0.64
NR_1_2	11	0.34	1.62	19	−1.08	1.70	0.03[a]
NL1	11	−1.72	2.50	19	−1.30	2.85	0.68
NL2	11	−2.90	2.61	19	−2.13	2.01	0.37
NL_1_2	11	−1.17	2.04	19	−0.83	2.11	0.67

S, silence; FN, frontal noise; NR, noise to the right; LN, noise to the left; 1, situation without hearing aids; 2, situation with hearing aids; *n*, number; SD, standard deviation; M, male gender; F, female gender.
[a] Statistically significant difference.

Table 5 Performance of subjects with unilateral loss at the Hearing In Noise Test (HINT – Brazil).

Situation proposed by HINT	Threshold	SD	*p*-Value
S1	40.62	3.89	0.06
S2	39.24		
FN1	−1.07	1.17	0.32
FN2	−1.29		
NR1	−2.84	1.79	0.09
NR2	−3.40		
NL1	−1.45	2.06	0.01[a]
NL2	−2.41		

S, silence; FN, frontal noise; NR, noise to the right; LN, noise to the left; 1, situation without hearing aids; 2, situation with hearing aids; *n*, number; SD, standard deviation.
[a] Statistically significant difference.

characteristics of individuals suffering this condition. The adaptation of hearing aids in this population still generates some questions as to the benefits provided to the patient.

Researchers investigated the benefit for, and satisfaction of, individuals with a diagnosis of mixed or sensorineural UHL (of a moderate, severe, or profound degree) with the use of hearing aids. They observed that, even without attaining the gain needed to meet the difficulties imposed by their hearing deprivation, these patients reported satisfaction with the use of amplification, relating it to an improvement of their quality of life.[16]

Individuals with UHL present greater difficulties than normal-hearing people to understand speech when the stimulus is presented together with a competing noise, even when the ear with better hearing threshold is positioned toward the speech.[14] Thus, tests that assess speech intelligibility in the presence of a competitive noise can provide relevant information about the communicative contexts that approximate the situations experienced in daily life.

Table 2 shows that only in the situation where noise was positioned toward the left ear (LE) of individuals with hearing impairment in this ear, the participants demonstrated better signal/noise (S/N) ratio than when noise was presented toward the LE of the participants with right ear (RE) hearing restriction. A study of individuals with UHL found that the cortical reorganization induced by unilateral hearing loss occurs mainly in individuals with hearing loss on the left side.

This suggests that the anatomical and functional changes related to brain plasticity are more likely to occur in the right hemisphere than in the left hemisphere.[17]

In people with normal hearing thresholds, hearing is the only sense in which each ear has its representation in both hemispheres, because the auditory pathways course through both ipsilateral and contralateral paths.[18]

In subjects with UHL, deficits may occur in their auditory processing and, consequently, in the development of language and communication.[19]

A study[18] has shown that individuals with hearing loss in their RE present a higher number of complaints related to the development of speech and language, as well as in their school performance. This probably demonstrates that hearing loss on the right side triggers a neurological immaturity of auditory pathways of the central nervous system that result from the stimulation coming from RE, *i.e.* from information that will be sent to the left hemisphere, which can also be related with a lower ability to inhibit competing noise.

The degree of hearing loss was a factor in the situation of noise to the right in subjects without a hearing aid device, as well as in the difference with and without hearing aids, when noise and stimulus were presented frontally.

A noisy environment presents itself as a challenging agent for speech intelligibility, especially for people with hearing loss, as the number of cues is reduced, causing these subjects to use only the cues at hand on the situation.

In this sample, it was observed that subjects with severe UHL showed greater difficulty in speech perception compared to subjects with moderate UHL. This can be explained by the reduction of binaural auditory cues as a result of hearing loss, since it is expected that normal hearing in both ears will assist in the detection and organization of speech in noise,[20,21] whereas the degree of hearing loss may have played an aggravating factor in test performance (Table 3). The results indicated significance in two situations, but better responses were observed in subjects with moderate hearing loss *versus* those with severe hearing loss, with respect to the S/N ratio.

In this sample, regarding gender, women have shown better performance in three situations of HINT-Brazil when compared with men (Table 4). Investigators[22] have reported that men and women process sound stimuli differently, which can be explained by the joint activation of the primary auditory cortex with the prefrontal cortex, which is activated at a higher intensity in women, even in the presence of an insignificant stimulus. The pre-frontal cortex participates in various cognitive processes, and has a modulating function in the activation of other cortical regions. For this reason, the superior performance of women compared to men in tasks with the presence of competing noise may be due to the superiority of maintaining attention to sound stimuli, and even to stimuli without meaning, such as noise. Thus, the different forms of brain activation among men and women may explain the better performance of women in the present study.

Analyzing the performance of individuals in situations with the use of hearing aids (Table 5), it was observed that in all test situations, a trend to improved S/N ratio was noted; this was more evident in the situation where noise was directed to the left. This finding demonstrates the importance of considering the benefits related to hearing aid fitting in patients with UHL, regarding the benefit that amplification can provide in order to minimize the difficulties imposed by this type of sensory deprivation.

Thus, additional studies are needed to better understand the characteristics and peculiarities of hearing aid fitting in individuals with UHL, to better meet the demands of these patients during the process of selection and verification of the hearing aid device.

Conclusion

In the HINT-Brazil, individuals with UHL demonstrated better performance in speech perception, both in a quiet environment and in situations with a competitive noise, with use of hearing aids.

Conflicts of interest

The authors declare no conflicts of interest.

References

1. Vieira MR, Nishihata R, Chiari BM, Pereira LD. Percepção de limitações de atividades comunicativas, resolução temporal e figura-fundo em perda auditiva unilateral. Rev Soc Bras Fonoaudiol. 2011;16:445–53.
2. Tharpe AM. Unilateral and mild bilateral hearing loss in children: past and current perspectives. Trends Amplif. 2008;12:7–15.
3. Bess F, Mckingley A, Murphy JD. Children with unilateral sensorineural hearing loss. Paediatr Audiol Med. 2002;3:249–313.
4. Ruscetta MN, Arjmand EM, Pratt SR. Speech recognition abilities in noise for children with severe-to-profound unilateral hearing impairment. Int J Pediatr Otorhinolaryngol. 2005;69:771–9.
5. Magni C, Freiberger F, Tonn K. Avaliação do grau de satisfação entre os usuários de amplificação de tecnologia analógica e digital. Braz J Otorhinolaryngol. 2005;71:650–7.
6. Trainor L, Sonnadara R, Wiklund K, Bondy J, Gupta S, Becker S, et al. Development of a flexible, realistic hearing in noise test environment (R-HINT-E). Signal Process. 2004;84:299–309.
7. Arieta AM, Couto CM, Costa EA. Teste de percepção da fala HINT Brasil em grupos de sujeitos expostos e não expostos a ruído ocupacional. Rev CEFAC. 2013;15:786–95.
8. Costa MJ. Lista de Sentenças em Português: apresentação e estratégias de aplicação na audiologia. Santa Maria: Pallotti; 1998. p. 26–36.
9. Wagener K, Josvassen JL, Ardenkjaer R. Design, optimization and evaluation of a Danish sentence test in noise. Int J Audiol. 2003;42:10–7.
10. Nilsson M, Soli SD, Sullivan JA. Development of the hearing in noise test for the measurement of speech reception thresholds in quiet and in noise. J Acoust Soc Am. 1994;95:1085–99.
11. Jacob RTS, Monteiro NFG, Bevilacqua MC, Lauris JRP, Moret ALM. Percepção da fala em crianças em situação de ruído. Arq Int Otorrinolaringol. 2011;15:163–7.
12. WHO. Grades of Hearing impairment. World Health Organization; 2009.
13. Dillon H. Hearing aids. 2nd ed. New York: Thieme; 2001.
14. Almeida K, Santos TMM. Seleção e adaptação de próteses auditivas em crianças. In: Almeida K, Iório MCM, editors. Próteses auditivas: fundamentos teóricos e aplicações clínicas. São Paulo: Lovise; 2003. p. 357–80.
15. HINT Pro Hearing in Noise Test User's and Service Manual. Mudelen, IL: Bio-logic Systems Corp. Biologic System Corp. House Ear Institute; 2007, 157 p. [Operating instructions HINT Pro 7.2 Audiometric system: Los Angeles].
16. José MR, Campos PD, Mondelli MFCG. Perda auditiva unilateral: benefício e satisfação com o uso do AASI. Braz J Otorhinolaryngol. 2011;77:221–8.
17. Hanss J, Veuillet E, Adjout K, Besle J, Collet L, Thai-Van H. The effect of long-term unilateral deafness on the activation pattern in the auditory cortices of French-native speakers: influence of deafness side. BMC Neurosci. 2009;10:23.
18. Nishihata R, Vieira MR, Pereira LD, Chiari BM. Processamento temporal, localização e fechamento auditivo em portadores de perda auditiva unilateral. Rev Soc Bras Fonoaudiol. 2012;17:266–73.
19. Feniman MR, Keith RW, Cunninghom RF. Assessment of auditory processing in children with attention deficit hyperactivity disorder and language-based learing impairments. Disturb Commun. 1999;11:9–27.
20. Jerger J, Brown D, Smith S. Effect of peripheral hearing loss on the masking level difference. Arch Otolaryngol. 1984;110:290–6.
21. Hall JW, Tyler RS, Fernandes MA. Factors influencing the masking level difference in cochler hearing impaired and normal hearing listeners. J Speech Hear Res. 1984;27:145–54.
22. Ruytjens L, Georgiadis JR, Holstege G, Wit HP, Albers FWJ, Willemsen ATM. Functional sex differences in human primary auditory cortex. Eur J Nucl Med Mol Imaging. 2007;34:2073–8.